CEPHALOPOD REMAINS IN REGURGITATIONS OF BLACK-BROWED AND GREY-HEADED ALBATROSSES AT SOUTH GEORGIA

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ABSTRACT. 122 regurgitations by adults and chicks of the small grey-headed and black-browed albatrosses (mollymauks) included, besides flesh remains, 421 upper beaks (mandibles) and 422 lower beaks of cephalopods. The lower beaks and some flesh remains were identified, their lower rostral lengths were measured and the wet weight of squids represented by beaks was estimated. Nine species of squid and one octopod were identified. In both species of albatross, the muscular ommastrephid squid *Todarodes* is the principal squid in the diet, contributing 88% of the beaks and an estimated 91% of the weight of cephalopods represented by beaks in grey-headed albatrosses and 68% of the beaks and 76% of the weight in black-browed albatrosses. Second in importance in the diet is a cranchiid *Mesonychoteuthis* sp. A, which contributes 8% and 25% by number and 4% and 12% by weight to the diet of grey-headed and black-browed albatrosses, respectively. The eight remaining species are each represented by either one or two lower beaks. These samples are compared with samples from sperm whale stomachs and wandering albatrosses also collected near South Georgia.

THE mollymauks *Diomedea chrysostoma,* the grey-headed albatross, and *D. melanophris,* the black-browed albatross, eat a mixture of cephalopods, fish and crustaceans. Tickell (1964) found that squid occurred in about 80% of the samples he obtained from regurgitations by the chicks of these two species. Prince (1980) has discussed these results in the light of his recent quantitative analysis of the diet of the two mollymauks. In this, using samples obtained from adults, he showed that squid comprise about 50% of the weight in the diet of grey-headed albatrosses and about 21% of the diet of black-browed albatrosses. In this paper the cephalopod element of the diet is examined in more detail.

The cephalopod remains consist of well-digested flesh including isolated bodies, heads, crowns (ring of arms), buccal masses and the upper and lower chitinous beaks or mandibles. In a total of 122 samples with cephalopod remains, 111 samples contained beaks. While the flesh was sometimes of value in helping with or confirming identifications, most of the identification relied upon recognition of the lower beaks which were little affected by digestive processes. The present collection is of particular interest since the cephalopod diet of these mollymauks contrasts with that of the wandering albatross (Clarke and others, 1981).

Detailed analyses of the cephalopods in the diet of sea birds have previously been carried out by Ashmole and Ashmole (1967; identified by MRC), Harris (1973; MRC), Imber (1973, 1976, 1978), and Imber and Russ (1975).

MATERIAL AND METHODS

Sampling was carried out between mid-January and March 1976 and 1977 at Bird Island, South Georgia, at lat. 54°S, long. 36°W in the South Atlantic. Most of the samples (72 from the grey-headed and 38 from the black-browed albatross) were collected from adults of both species as they were about to feed their chicks. Twelve of the 122 samples containing cephalopod remains were from regurgitations by chicks (ten of these from the grey-headed albatross). The squid lower beaks were identified by comparison with beaks removed from specimens and described elsewhere (Clarke, 1962*a, b,* 1980; Clarke and MacLeod, 1974, 1976; Clarke and Stevens, 1974; Clarke and others, 1976). The present analysis depends upon techniques developed from an early search for criteria (Clarke, 1962*b*) to a point where many species can be readily identified from lower beaks (Mangold and Fioroni, 1966; Iverson and Pinkas, 1971; cited papers by Clarke and others).

Lower rostral lengths (LRL) were measured with vernier calipers to an accuracy of 0.005 cm.

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LRL distributions of the more numerous species (Fig. 1) and the size at which the lower wings become dark are employed in comparisons with previously described collections. Unless otherwise stated, comparisons with the diet of sperm whales are with data given by Clarke (1980). LRL to wet weight of squid relationships are used to calculate percentage weights of the various species of cephalopod in the diet (Clarke, 1962*b*, 1980).

Results

Grey-headed albatross diet

The 82 samples included 322 upper beaks and 322 lower beaks of cephalopods. 315 lower beaks were identified as six cephalopod species and over 88% of the beaks are *Todarodes*.

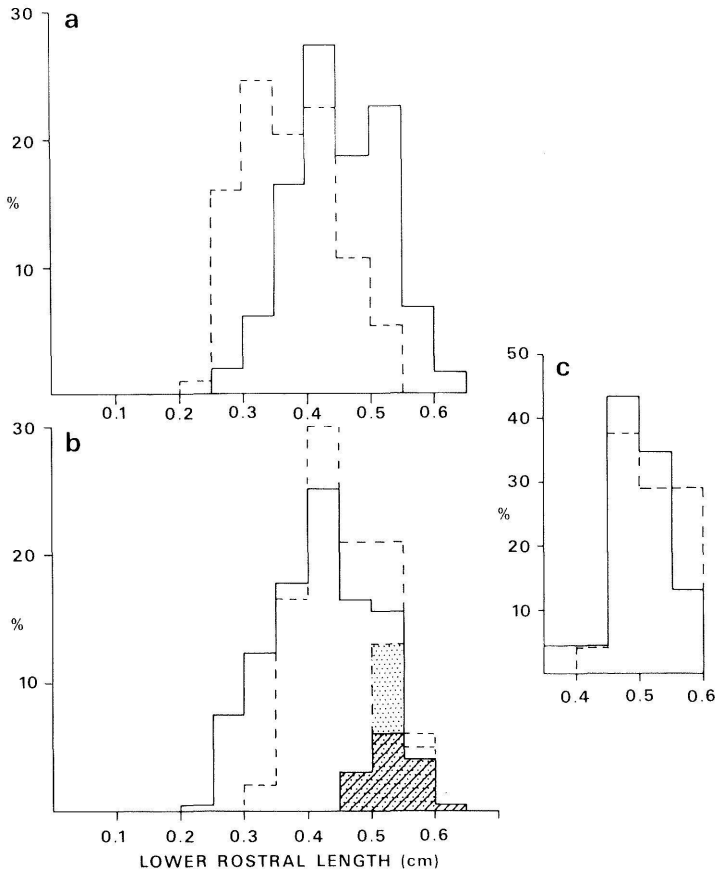

Fig. 1. Lower rostral length percentage distributions of cephalopod beaks from regurgitations of albatrosses (mollymauks) at South Georgia.
a. *Todarodes (?) sagittatus* from grey-headed albatross chicks (dashed) and adults.
b. *Todarodes (?) sagittatus* from all grey-headed and black-browed albatrosses (dashed). Beaks with isolated dark patches on the wings or patches with very narrow connections to the darkened hood are hatched (grey-headed albatrosses) or dotted (black-browed albatrosses). Other beaks have transparent or no wings (suggesting that transparent wings were present before digestion by the bird).
c. *Mesonychoteuthis* sp. A from grey-headed and black-browed (dashed) albatrosses.

FAMILY OMMASTREPHIDAE

Todarodes (?) sagittatus (Lamarck, 1799)

Although much flesh of this species was present in the samples, it was in too poor a condition to identify positively the species to which this *Todarodes* belongs, but the species is probably *T. sagittatus*. The species contributes 88.2% of the lower beaks and an estimated 91.4% to the weight of cephalopods in the diet (Table I). The lower rostral length (LRL) distribution of this species (Fig. 1b) has a mode of 0.40–0.45 cm and a range of 0.23–0.61 cm. These beaks are much smaller than the beaks of this species from sperm whales which are nearly all over 0.9 cm in LRL. Darkening of the wings of the lower beaks to the right of the size distribution (Fig. 1b) indicates that the individuals sampled by these albatrosses are immature while the sperm whales eat almost exclusively "mature" individuals. The size of the beaks when the wings become darkened is close to that of *Todarodes* from sperm whales and *T. sagittatus* from the North Atlantic (Clarke, 1962*b*).

The LRL size distribution of *Todarodes* from chick and adult regurgitations are significantly different (Fig. 1a) and a possible explanation is that the chicks were sampled in January, while most of the adults were sampled in February and March; thus the increment may reflect growth of the squids during 1 month.

FAMILY CRANCHIIDAE

Mesonychoteuthis sp. A

Several crowns with buccal masses were collected which have arms with suckers having either rings or hooks. The chitin of the rings and hooks was affected by digestion so that their misshapen form appeared as if they had been melted. However, hooks and rings are apparently arranged as in *Mesonychoteuthis hamiltoni* Robson, in which the middle suckers of the arms have chitinous hooks while the basal and apical suckers have chitinous rings. This arrangement shows that this species, which the tattered flesh remains and the beak show to be a cranchiid, belongs to the genus *Mesonychoteuthis*. The lower beaks are closely similar to *Galiteuthis (?) armata* and are indistinguishable from McSweeney's (1970) description and figure of beaks of specimens he referred to *Mesonychoteuthis hamiltoni*. His figure shows the lower beak with darkened wings at a much smaller size than is usual for *Mesonychoteuthis hamiltoni* Robson in which darkening takes place above an LRL of 1.2 cm (Clarke, 1980). This shows that McSweeney's specimens were not *M. hamiltoni* but should be placed in a second species of the genus. The smallest lower beaks grouped here have darkened wings and are therefore probably the same species as McSweeney's specimens. This cannot be definitely resolved without further material and the species will be called *Mesonychoteuthis* sp. A.

TABLE I. CEPHALOPOD BEAKS IN THE REGURGITATIONS OF ADULTS (72 SAMPLES) AND CHICKS (10) OF THE GREY-HEADED ALBATROSS AT SOUTH GEORGIA

		Beaks		*Estimated weights*		
		Number	%	*Mean* (kg)	*Total* (kg)	*Total* (%)
Ommastrephidae	*Todarodes (?) sagittatus*	284	88.2	0.157	44.9	91.4
Histioteuthidae	*Histioteuthis*	2	0.6	0.054	0.1	0.2
Mastigoteuthidae	*Mastigoteuthis*	2	0.6	0.077	0.2	0.4
Chiroteuthidae	*Chiroteuthis*	1	0.3	0.090	0.1	0.2
Cranchiidae	*Mesonychoteuthis* sp. A	24	7.5	0.075	1.9	3.9
Onychoteuthidae	*Kondakovia*	2	0.6	0.940	1.9	3.9
Unidentified other species		7	2.2	—	—	—
TOTAL		322	100.0	0.146	49.1	100.0

This species, the beak of which has been described from wandering albatrosses (Clarke and others, 1981) contributes only 7.5% of the beaks and an estimated 3.9% to the weight of cephalopods in the diet (Table I). The LRL distribution of the species has a mode at 0.45–0.50 cm and a range of 0.35–0.60 cm (Fig. 1c). These beaks are therefore slightly smaller than beaks of the same species in wandering albatrosses with a mode at 0.50–0.55 cm and a range of 0.46–0.63 cm.

FAMILY HISTIOTEUTHIDAE

Histioteuthis (?) eltaninae Voss, 1969

Two lower beaks from chicks had LRLs of 0.3 cm and represent 0.6% of all lower beaks. Their form, size and stage of darkening strongly suggest that they belong to this Antarctic species of *Histioteuthis,* beaks of which were identified in stomach contents of sperm whales. The two squids only contribute an estimated 0.2% to the weight of flesh represented by beaks in the collection. This species comprised 10.1% of the lower beaks in wandering albatrosses (Clarke and others, 1981).

FAMILY MASTIGOTEUTHIDAE

Mastigoteuthis sp.

Two lower beaks with LRLs of 0.46 and 0.37 cm belong to a species of this genus. They are outside the size range of 13 beaks of members of the genus collected from wandering albatrosses which had LRLs 0.5–0.8 cm (Clarke and others, 1981).

FAMILY CHIROTEUTHIDAE

Chiroteuthis (?) veranyi (Férussac, 1835)

One beak from a chick having an LRL of 0.58 cm belongs to this genus and is indistinguishable from *C. veranyi,* which was recorded from wandering albatross regurgitations (Clarke and others, 1981).

FAMILY ONYCHOTEUTHIDAE

Kondakovia longimana Filippova, 1972

One beak from a chick has no wings at a rostral length (to the end of the hood) of 1.09 cm and belongs to this species. A buccal mass of this species with a beak having an LRL of 1.09 cm and dark wings was taken from an adult albatross. In this species wings darken at 0.9–1.2 cm.

Black-browed albatross diet

Besides many well-digested parts of squids and an octopus, the 40 samples included 99 upper beaks and 100 lower beaks of cephalopods. The lower beaks were from eight species with *Todarodes (?) sagittatus* and *Mesonychoteuthis* sp. A accounting for 93% of all lower beaks as compared with 96% in grey-headed albatrosses.

FAMILY OMMASTREPHIDAE

Todarodes (?) sagittatus (Lamarck, 1799)

This species comprises 68% of the beaks and an estimated 75.9% of the weight of cephalopod flesh represented by beaks in the diet (Table II). The LRL distribution of the species from black-browed albatrosses is very similar to those collected from grey-headed albatrosses with a mode in both at 0.4–0.45 cm (Fig. 1b).

Only three of these cephalopod lower beaks were from chicks.

TABLE II. CEPHALOPOD BEAKS IN THE REGURGITATIONS OF ADULTS (38 SAMPLES) AND CHICKS (2) OF THE BLACK-BROWED ALBATROSS AT SOUTH GEORGIA

		Beaks		*Estimated weights*		
		Number	%	*Mean* (kg)	*Total* (kg)	*Total* (%)
Ommastrephidae	*Todarodes (?) sagittatus*	68	68	0.185	12.6	75.9
Onychoteuthidae	*Kondakovia*	1	1	0.158	0.2	1.2
Enoploteuthidae	*(?) Enoploteuthis*	1	1	0.203	0.2	1.2
	Ancistrocheirus	1	1	1.110	1.1	6.6
Chiroteuthidae	*Chiroteuthis*	2	2	0.077	0.2	1.2
Gonatidae	*Gonatus* sp. A	1	1	0.156	0.2	1.2
Cranchiidae	*Mesonychoteuthis* sp. A	25	25	0.081	2.0	12.0
Octopodidae	*(?) Pareledone*	1	1	0.059	0.1	0.6
TOTAL		100	100	0.166	16.6	99.9

FAMILY CRANCHIIDAE

Mesonychoteuthis sp. A

This species contributes 25% of the beaks and an estimated 12.0% of the weight of cephalopods represented by beaks in the diet (Table II). The LRL distribution is very similar to the same species collected from grey-headed albatrosses (Fig. 1c).

FAMILY CHIROTEUTHIDAE

Chiroteuthis (?) veranyi (Férussac, 1835)

Two crowns with beaks having LRLs of 0.55 cm belong to this species which also occurred in the diet of the grey-headed albatross. The flesh confirmed the generic but not the specific identifications.

FAMILY ONYCHOTEUTHIDAE

Kondakovia longimana Filippova, 1972

One beak of this species with an LRL of 0.78 cm was collected. This species is important in the diet of the wandering albatross in which all but one of the 167 beaks measured had LRLs over 0.9 cm (Clarke and others, 1981). The beak had transparent wings, indicating that it was from an immature squid.

FAMILY ENOPLOTEUTHIDAE

Ancistrocheirus lesueuri (d'Orbigny, 1839)

A crown having a beak with an LRL of 0.76 cm was from this species. The squid's weight was estimated as 1 110 g and this probably contributed about 7% to the total weight of cephalopod flesh represented by lower beaks in the collection. This species is also in the diet of wandering albatrosses and sperm whales (Clarke and others, 1981). The size of the beak falls within the range found in these two other predators.

(?) Enoploteuthis sp.

One beak with an LRL of 0.47 cm closely resembled one taken from an *Enoploteuthis leptura* specimen and probably belongs to this genus. The weight of the individual from which the beak came was estimated from the LRL-to-weight relationship for *Ancistrocheirus* (Clarke, 1980).

FAMILY GONATIDAE

Gonatus sp. A

One beak with an LRL of 0.56 cm belongs to the smaller of the two species of this genus described from the diet of wandering albatrosses (Clarke and others, 1981).

FAMILY OCTOPODIDAE

(?) Pareledone sp.

A head and a separate body of an octopus was collected from an adult. It is partly digested but is a male with a well-developed hectocotylus, arm suckers which are mainly in a single row and an ink sac. Its lower crest length is 0.53 cm and the head and body together weigh 58.8 g. It probably belongs to the genus *Pareledone.*

DISCUSSION

The cephalopod part of the diet of both the grey-headed and the black-browed albatrosses is very similar. In both, *Todarodes (?) sagittatus* is the principal cephalopod contributing about 91% and 76% by weight, respectively, and *Mesonychoteuthis* sp. A is the second in importance contributing about 4% and 12% by weight, respectively. The beak sizes of these two cephalopods are much the same in the two species of albatross (Fig. 1b and c).

More chicks were sampled of grey-headed than of black-browed albatrosses and these were found to regurgitate smaller beaks of *Todarodes* than do the adults (Fig. 1a). This difference is probably a reflection of the time sampling was carried out. The chicks were sampled mainly in January and the adults in February and March, and the size difference of about 0.1 cm in LRL is possibly due to growth of the squids.

Besides the two principal cephalopod species in the diet, both albatrosses had only one or two beaks of eight other species in seven families. Only two of these species, *Chiroteuthis (?) veranyi* and *Kondakovia longimana,* occurred in both species of albatross. This suggests that feeding is directed towards the *Todarodes (?) sagittatus,* which certainly approaches near the sea surface towards the colder limits of its range (Clarke, 1966), and the *Mesonychoteuthis* sp. A, but opportunistic feeding on other squids also occurs. *Todarodes* individuals of the size sampled come very near to the sea surface at night and living individuals are very probably caught by the albatrosses. Although, with the exception of *Pareledone,* the other species are deep-living oceanic squids, the beaks are all, with the exception of *Ancistrocheirus,* small and it is not unlikely that small individuals come sufficiently near the sea surface to also fall a living prey to these albatrosses. However, the *Ancistrocheirus* beak is large (LRL = 0.76 cm) and our present knowledge of this species suggests that it is unlikely such a large individual would come sufficiently near to the sea surface for an albatross to catch it. It seems, therefore, more likely that this individual was scavenged when dead rather than caught alive by the albatross.

Seven out of the nine species of squid in the diet of the two albatrosses have photophores but, as argued elsewhere (Clarke and others, 1981), these are directed downward in most species and would therefore be unlikely to be a great aid to the albatross in detecting the squids at night. However, there is at present no evidence to suggest that squids of the genera and size eaten would approach the sea surface in daylight. Vertically migrating squids start to move down before nautical twilight in the morning and evening but stragglers can sometimes be observed from ships at dawn and dusk so that this would be the most likely time for these albatrosses to catch squids.

Of the squids eaten, only *Kondakovia longimana, Histioteuthis eltaninae* and possibly *Mesonychoteuthis* sp. A are thought to be limited to the Antarctic. *Todarodes (?) sagittatus* and *Ancistrocheirus lesueuri* extend from warmer waters into the vicinity of South Georgia where they are also eaten by sperm whales.

The regurgitations contained the remains of an average of less than four cephalopods.

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Note added in proof

A recent opportunity to examine the beaks described by McSweeney (1970) and other material kindly made available by Dr Nancy Voss showed that the beaks described here as *Mesonychoteuthis* sp. A should most probably be referred to *Galiteuthis glacialis* rather than to a small *Mesonychoteuthis* species.